DOCUMENT RESUME

ED 045 400 SE 010 127

TITLE	Employment Outlook, Environmental Scientists, Geologists, Geophysicists, Meteorologists, Oceanographers.
INSTITUTION	Department of Labor, Washington, D.C. Bureau of Labor Statistics.
REPORT NO	Bull-1650-24
PUB DATE	70
NOTE	15p.
AVAILABLE FROM	Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (Cat. No. L 2.3:1650-24, $0.15)
EDRS PRICE	EDRS Price MF-$0.25 HC Not Available from EDRS.
DESCRIPTORS	Earth Science, *Employment, *Employment Opportunities, *Employment Trends, Geology, Geophysics, Meteorology, *Occupational Guidance, Oceanology

ABSTRACT

Described is employment in four branches of earth science: geology, geophysics, meteorology, and oceanography. Considered for each employment area is the nature of the work, places of employment, type of training and qualifications for advancement, employment outlook, and earnings and working conditions. The demand for specialists in these four areas is expected to increase during the 1970's. Employment opportunities should be good, expecially for those with master's and doctor's degrees. Those geologists with only a bachelor's degree will probably face heavy competition for jobs, depending on the hiring practices of the petroleum industry. Sources of additional information are listed for each employment field, and a complete listing of the Occupational Outlook Reprint Series (for all employment areas) is included. (PR)

ED045400

Employment Outlook

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
OFFICE OF EDUCATION

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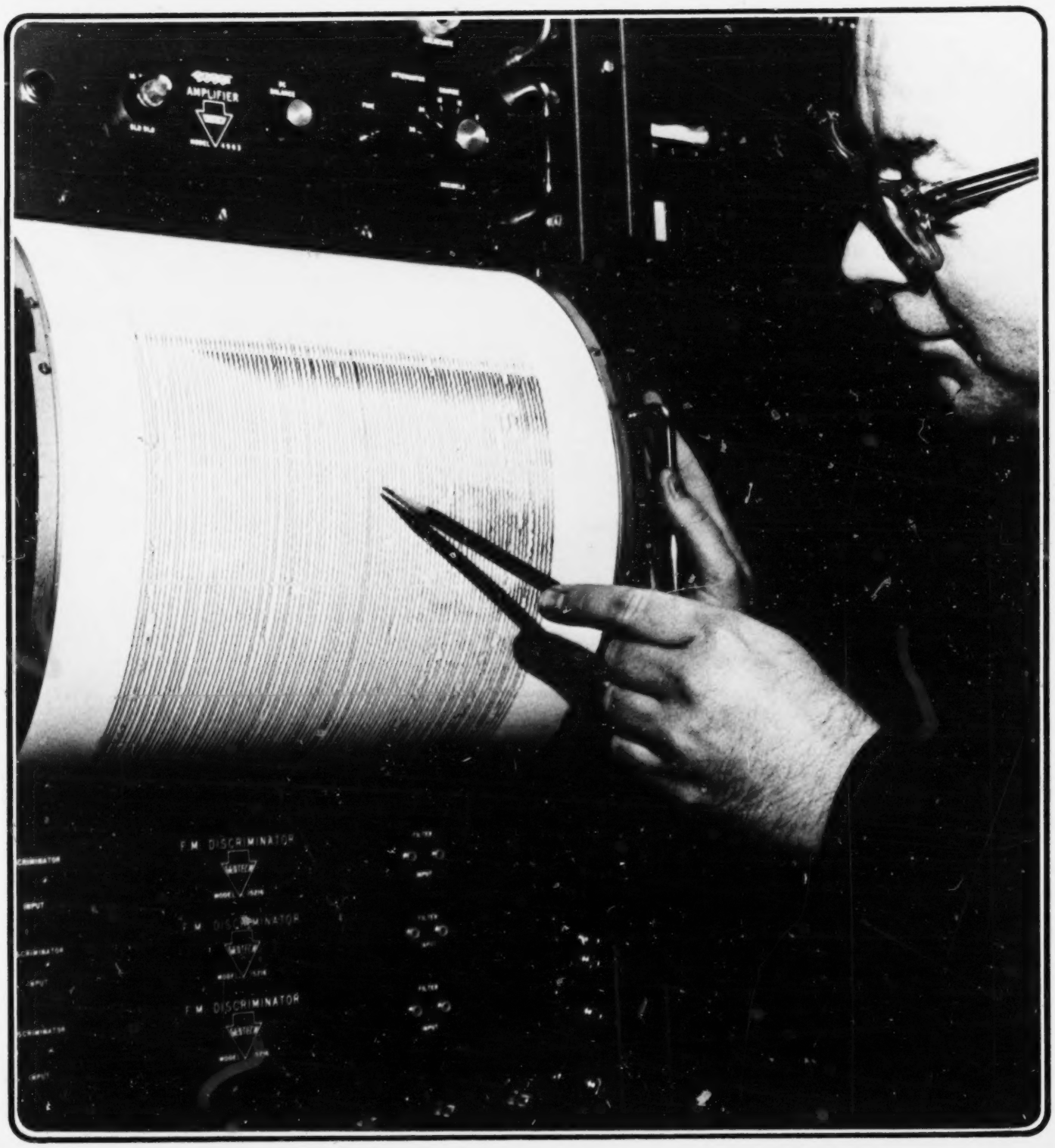
Environmental Scientists

- Geologists
- Geophysicists
- Meteorologists
- Oceanographers



SE 010 127

A Reprint from the Occupational Outlook Handbook, 1970-71 Edition

U.S. Department of Labor
Bureau of Labor Statistics
Bulletin 1650-24

Environmental sciences

The environmental sciences are concerned with the history composition, and characteristics of the earth's land, water, interior, atmosphere, and its environment in space. A large group of the scientists in this field explore for new sources of mineral fuels and ores. Some scientists perform basic research to increase scientific knowledge. Others work mainly in applied research use knowledge gained from basic research to solve practical problems. Meteorologists, for example, apply scientific knowledge of the atmosphere to forecast weather conditions for specific localities and times. Some of these scientists teach in colleges and universities. They also may administer scientific programs and operations.

Many environmental scientists specialize in one particular branch of their broad occupational field. Geophysicists, for example, may be specialists in geodesy, hydrology, seismology, or physical oceanography. This chapter discusses the specialties and the employment outlook for four environmental science occupations —geologist, geophysicist, meteorologist, and oceanographer.

GEOLOGISTS

(D.O.T. 024.081)

Nature of the Work

Geologists study the structure, composition, and history of the earth's crust. Many geologists spend a large amount of their time in field work. They study rock cores and cuttings from deep holes drilled into the earth and examine rocks, minerals, and fossils found at or near the surface of the earth. Geologists also spend considerable time in laboratories, where they study geological specimens, analyze geological materials under controlled temperature and pressure, and do other research on geological processes. To present the results of their field and laboratory investigations, geologists prepare reports, articles, and maps of surface and subsurface geological phenomena. In their work, geologists use a variety of complex instruments, such as the X-ray diffractometer, which determines the structure of minerals, and the petrographic microscope, which permits close study of how rocks have been formed and modified by earth processes.

Some geologists administer research and exploration programs. Others teach in colleges and universities, where they also may work on research projects.

Geologists usually specialize in one branch of the science. *Economic geologists* find and supervise the development of mineral and fuel resources. *Petroleum*

Research geologist pans stream sediments for heavy metals.

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402 – Price 15 cents

geologists specialize in the discovery and recovery of oil and natural gas. *Engineering geologists* apply geological knowledge to engineering problems in the construction of roads, airfields, tunnels, dams, harbors, and other large structures. *Stratigraphers* study the distribution and relative arrangement of sedimentary rock layers by analyzing their fossil and mineral content. *Sedimentologists* determine the processes and prodcts involved in the formation of sedimentary rocks, and *paleontologists* identify, classify, and determine the significance of fossils found within the sediments. *Petrologists* classify and determine the origins of rock masses. *Mineralogists* examine, analyze, and classify minerals and precious stones according to their composition and structure. *Geomorphologists* study the form of the earth's surface and the forces, such as erosion and glaciation, which change it.

Increasing numbers of geologists specialize in new fields that require a detailed knowledge of both geology and one or more other sciences. Among these specialists are *geochemists*, who study the chemical composition of and the changes in minerals and rocks, and *astrogeologists*, who use knowledge of the earth's geology in studies of surface conditions on the moon and the planets. *Geological oceanographers* study the sedimentary and other rocks on the ocean floor and continental shelf. (See statement on Oceanographers elsewhere in this chapter.)

Places of Employment

Nearly 23,000 geologists were employed in the United States in 1968; only about 3 percent were women. Nearly three-fifths of all geologists worked for private industry, mostly for petroleum and natural gas producers. A number of the employees of American petroleum companies worked in foreign countries. Geologists also were employed by companies engaged in various other types of mining. Some geologists specialized in problems related to the construction of dams, bridges, buildings, and highways. Still other geologists worked as independent consultants offering specialized services to industry and government.

The Federal Government employed approximately 2,000 geologists, two-thirds of whom worked for the Department of the Interior in the U.S. Geological Survey, the Bureau of Mines, and the Bureau of Reclamation. State agencies also employed geologists, some of whom worked on surveys conducted in cooperation with the U.S. Geological Survey. Although a few positions were in foreign countries, most Federal jobs were in the United States.

Colleges and universities employed more than 4,500 geologists. A few others worked for nonprofit research institutions and museums.

Training, Other Qualifications, and Advancement

Young people seeking professional careers in geology should plan to earn an advanced degree. The master's degree is required for beginning research and teaching positions and for many positions in exploration. Advancement in college teaching as well as in high-level research and administrative posts usually requires the Ph. D. degree. The bachelor's degree is considered adequate training for only a few entry jobs, primarily in exploration work.

About 350 colleges and universities offer the bachelor's degree in geology. In the typical undergraduate curriculum, students devote about one-fourth of their time to geology courses, such as historical geology, structural geology, mineralogy, petrology, and invertebrate paleontology. About another third of the work is in mathematics, the related natural sciences—such as physics, geophysics, chemistry, and biology—and in engineering; the remainder is in general academic subjects.

More than 200 universities award advanced degrees in geology. The student seeking a graduate degree in geology takes advanced courses in geology, with emphasis on the student's area of specialization.

The student planning a career in exploration geology should like outdoor activities and have the physical stamina for geological field work, which frequently involves camping out. This is not a requirement, even though it is an excellent way to get training. An increasing amount of the work, formerly done in the field, is now accomplished by aerial photography. In addition, a growing number of specialties are laboratory-oriented.

Employment Outlook

Employment opportunities for geologists having advanced degrees are expected to be favorable through the 1970's. However, those having the bachelor's degree, including those who rank high in their class, probably will face competition for entry positions, depending largely on the hiring practices of petroleum companies. A number of new graduates having the bachelor's degree may find it necessary to enter semiprofessional positions, such as technician or surveyor. Some may take training to qualify as science teachers in secondary schools, or seek other work outside the field of geology.

Replacement needs are expected to be the chief source of openings. More than 800 new geologists will be required each year to replace those who are promoted to managerial positions or who transfer to other fields, retire, or die.

As world population expands and nations become more industrialized, the demand for petroleum, minerals, and fresh water will rise, and increasing numbers of geologists will be required to locate these resources. Geologists will be needed to devise techniques for exploring deeper within the earth's crust, both on land and under the sea, and to work with engineers to develop more efficient methods of recovering natural resources. Space-age activities will require some geologists to analyze data on the surface conditions of the moon and the planets.

During the next few years, private industry probably will employ more geologists than formerly. Domestic petroleum exploration activities, which declined in the late 1950's, are expected to continue to expand in the 1970's. The nature of exploration activities is such that the need for geologists may vary widely from one year to the next, and the shortrun demand for geologists occasionally exceeds the number of persons available for these activities. Geologists also will be needed to help solve problems related to construction, water supply, and improved methods of locating mineral resources.

Federal agency demand for geologists is expected to grow moderately, primarily in the U.S. Geological Survey. Employment of geologists by colleges and universities will probably rise slightly; the need will be mainly for those having Ph. D. degrees who are capable of performing high-level research.

The demand for earth science teachers in secondary schools is expected to increase very rapidly in the next decade. Geology graduates having the bachelor's degree, but who have had additional training in educational methods, should have good opportunities in this area.

Earnings and Working Conditions

The average (median) annual starting salary for new geology graduates who have a bachelor's degree was $7,800 in private industry in 1968, according to the American Geological Institute's annual survey. New graduates who have a master's degree usually started at between $1,000 and $1,500 more a year than those having the bachelor's degree. Starting salaries for those who have doctor's degrees averaged $12,000 a year.

Depending on their college records, new graduates who have a bachelor's degree could begin at either $7,456 or $8,845 a year in late 1968 in the Federal Government. Those who have a master's degree could start at $8,845 or $9,872, and those who have the Ph.D. degree, at $10,883 or $12,174.

Teachers often supplement their regular salaries with income from research, consulting, or writing. Extra allowances generally are paid geologists for work outside the United States.

The work of geologists is often active and sometimes strenuous. When their work is outdoors, geologists may be exposed to all kinds of weather. Many geologists travel a great deal and may do fieldwork away from home for long periods. Their hours of work often are uncertain because their field activities are affected by weather and travel.

Sources of Additional Information

General information on career opportunities, training, and earnings for geologists may be obtained from:

American Geological Institute, 2201 M St. NW., Washington, D.C. 20037.

Information on Federal Government careers may be obtained from:

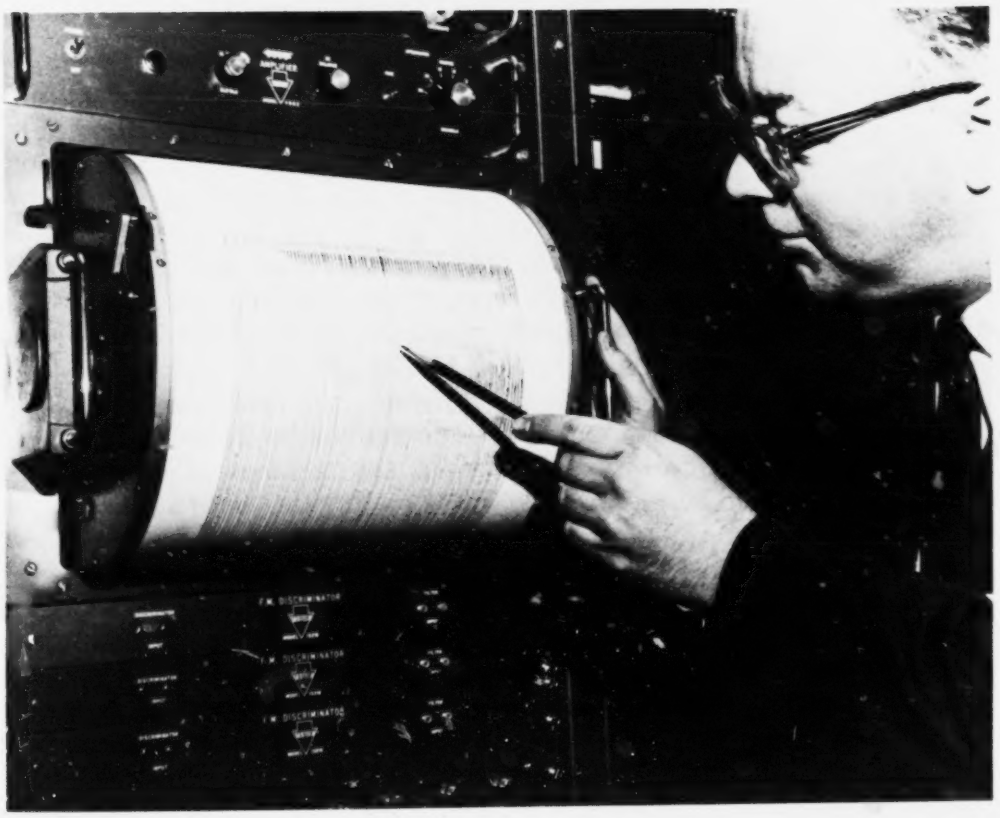
Interagency Board of U.S. Civil Service Examiners for Washington, D.C., 1900 E St. NW., Washington, D.C. 20415.

GEOPHYSICISTS

(D.O.T. 024.081)

Nature of the Work

Geophysics is an overall term covering a number of sciences concerned with the composition and physical aspects of the earth —its size and shape, interior, surface, atmosphere, the land and bodies of water on its surface and underground, and the environment of the earth in space. Geophysicists study the earth's physical characteristics, such as its electric, magnetic, and gravitational fields; the earth's interior heat flow and vibrations; and solar radiation. To conduct their investigations, geophysicists apply the principles and techniques of physics, geology, meteorology, oceanography, geodesy, mathematics, chemistry, and engineering. They use many instruments, including highly complex precision ones such as the seismograph, which measures and records the transmission time and magnitude of earthquake waves or vibrations through the earth; the magnetometer, which measures variations in the earth's magnetic field; and the gravimeter, which measures minute variations in gravitational at-



Geophysicist examines seismogram.

traction. In geophysical exploration, increasing use is being made of electronic computers to collect and process pertinent data.

Exploration geophysicists search for oil and mineral deposits, using the knowledge of earthquake vibrations, the magnetic field, gravitational attraction, and other basic geophysical techniques. Others conduct research, usually to develop new or improved techniques and instruments for prospecting.

Hydrologists study the occurrence, circulation, distribution, and physical properties of surface and underground waters in the land areas of the earth. Some hydrologists are concerned with water supplies, irrigation, flood control, and soil erosion.

Seismologists study the structure of the earth's interior and the vibrations of the earth caused by earthquakes and manmade explosions. They may explore for oil and minerals, provide information for use in designing bridges, dams, and buildings in earthquake regions, or study the problems involved in detecting underground nuclear explosions.

Geodesists measure the size and shape of the earth, determine the positions and elevations of points on or near the earth's surface, and measure the intensity and direction of gravitational attraction. They track satellites orbiting in outer space to study the size and shape of the earth and the distributions of mass within the earth.

Geomagneticians and aeronomists are concerned with the earth's magnetic field—its variations, courses, and form in space —and with many aspects of space science.

Tectonophysicists study the structure of mountains and ocean basins, the properties of materials forming the earth's crust, and the physical forces that formed the mountains and the ocean basins.

Oceanographers and meteorologists, sometimes classified as geophysical scientists, are discussed separately in this chapter, as is the closely related occupation of geologist.

Places of Employment

Nearly 7,000 geophysicists were employed in the United States in 1968. Private industry employed a majority of all geophysicists, chiefly in the petroleum and natural gas industry. Other geophysicists were employed by mining companies, exploration and consulting firms, and research institutions. A few were in business for themselves as consultants and provided services on a fee or contract basis to companies and individuals engaged in prospecting or other activities utilizing geophysical techniques.

Geophysicists in private industry were employed mainly in the southwestern and western sections of the United States, including the Gulf Coast, where most of the country's large oil and natural gas fields and mineral deposits are located. Some geophysicists employed by American firms are assigned to work in foreign countries for varying periods of time.

In 1968, Federal Government agencies employed more than 1,200 geophysicists, geodesists, and hydrologists, mainly the U.S. Geological Survey; the Coast and Geodetic Survey and the Institute for Earth Sciences of the Environmental Science Services Administration; the Army Map Service; and the Naval Oceanographic Office. Colleges and universities, State governments, and nonprofit research institutions employed small numbers of geophysicists.

Training, Other Qualifications, and Advancement

A bachelor's degree with a major in geophysics or in one of the geophysical specialties qualifies young persons for many beginning jobs in exploration geophysics. A bachelor's degree in a related science or in engineering, including courses in geophysics, physics, geology, mathematics, chemistry, and engineering, also is adequate preparation for many beginning jobs, especially in geophysical exploration. Some background in electronic data processing is useful.

For geophysical specialties other than exploration, and for the more responsible positions in exploration work, graduate education in geophysics or in a related physical science usually is required. A doctor's degree with a major in geophysics, or in a related science with advanced courses in geophysics, generally is required for teaching careers. The Ph. D. is required frequently for positions involving fundamental research and for advancement in most types of geophysical work.

The bachelor's degree in geophysics is awarded by less than 20 colleges and universities. These undergraduate programs provide training chiefly in exploration geophysics. Other curriculums that offer the required training for beginning jobs as geophysicists include geophysical technology, geophysical engineering, engineering geology, petroleum geology, and geodesy.

The master's degrees and Ph. D. in geophysics are granted by about 15 universities. For admission to a graduate program, a bachelor's degree with a good background in geology, mathematics, physics, or engineering, or a combination of these subjects is the usual requirement. In general, the graduate student should attend a school in which he can take advanced courses and carry out research projects in the aspect of geophysical science in which he has a special interest.

Beginning geophysicists having only the bachelor's degree are usually given on-the-job training in the application of geophysical principles to their employers' projects. If a new employee has not taken the courses in geophysics needed for his job, he is taught geophysical methods and techniques on the job.

Federal Government agencies also have training programs in which a few geophysicists are sent each year to universities for graduate training. Some Federal Government agencies provide a few summer jobs for promising undergraduates and make permanent positions available to them after graduation.

The prospective geophysicist should be energetic and in excellent health, since geophysicists often have to work outdooors under somewhat rugged conditions. A willingness to travel is also important, since a geophysicist may be required to move from place to place in the course of his employment.

Employment Outlook

Employment opportunities for the few new graduates having degrees in geophysics are expected to be good through the 1970's. Opportunities will be best for those having the master's or doctor's degree. There also should be favorable opportunities in geophysical work for well-qualified people having degrees in other sciences if they have had some formal training in geophysics.

Moderate growth is expected in this profession through the 1970's. Federal Government agencies will need geophysicists for new or expanded geophysical programs. The petroleum and mining industries will need geophysicists for exploration activities which are expected to expand in the 1970's. Several hundred new geophysicists also will be needed each year to replace those who leave the profession, retire, or die.

Although the number of job openings for geophysicists is not expected to be large in any one year, the number of new graduates having degrees in the science also is expected to be small. As in past years, the number of geophysics graduates who are seeking work as geophysicists probably will be insuffiicent to meet employers' needs, and well-trained persons having degrees in related sciences and in engineering probably will continue to be hired for geophysical positions.

Over the long run, further growth in the profession is expected. There will be increasing use of petroleum and mineral products by a growing population. As natural resources in the more easily accessible locations become depleted, additional exploration geophysicists will be needed by petroleum and mining companies to find the more concealed sites of fuels and minerals. In addition, the growing importance of basic research in the geophysical sciences, as well as the continuing need to develop new geophysical techniques and instruments, will create a demand for personnel having advanced training in hydrology, seismology, geodesy, and other geophysical specialties. In Federal Government agencies, additional geophysicists probably will be needed to study the problems of the Nation's water supplies and mineral resources; to work on flood control; to do research in radioactivity and cosmic and solar radiation; and to explore the outer

atmosphere and space, using such vehicles as sounding rockets and artificial satellites.

Earnings and Working Conditions

In private industry in 1968, new graduates having bachelor's degrees typically received starting salaries between $7,500 and $9,000 a year, according to the limited information available. New graduates having master's degrees received about $1,500 more than those having the bachelor's degree. Those having doctor's degrees received salaries of between $11,000 and $13,000, depending upon individual qualifications. In private industry, geophysical scientists working outside the United States usually receive bonuses and allowances.

In the Federal Government in late 1968, graduates having bachelor's degrees and no experience could enter most types of geophysical work at either $7,456 or $9,078 a year, depending upon their college records. Those who had completed all requirements for the master's degree could start at $9,078 or $10,154; those having the Ph.D. could start at $11,563 or $12,580. In the Federal Government as in industry, geophysicists stationed outside the United States are paid an additional amount.

In educational institutions, starting salaries are generally lower than in private industry or in the Federal Government. University teachers, however, may supplement their income by consulting, writing, or research activities.

The work of geophysicists is often active and sometimes strenuous. Exploration geophysicists are subject to reassignment in various locations as exploration activities shift. Their working hours may be irregular and frequently are determined by the requirements of field activities.

Sources of Additional Information

General information on career opportunities for geophysicists may be obtained from:

American Geophysical Union, 2100 Pennsylvania Ave. NW., Washington, D.C. 20037.

Society of Exploration Geophysicists, P. O. Box 3098, Tulsa, Okla. 74101.

Information on Federal Government careers may be obtained from:

Interagency Board of U.S. Civil Service Examiners for Washington, D.C., 1900 E St. NW., Washington, D.C. 20415.

METEOROLOGISTS

(D.O.T. 025.088)

Nature of the Work

Meteorology is the study of atmospheric phenomena—not only of the earth, but of all celestial bodies. Meteorologists attempt to describe and understand the at-

mosphere's constituents, motions, processes, and influences. Their knowledge helps solve many practical problems in agriculture, transportation, communications, health, defense, and business.

Meteorologists usually specialize in one branch of the science. Weather forecasters known professionally as *synoptic meteorologists*, are the largest group of specialists. They interpret current weather information (such as air pressure, temperature, humidity, wind velocity) reported by observers in many parts of the world and by radiosondes and weather satellites to make short- and long-range forecasts for specific regions. *Climatologists* analyze past records on wind, rainfall, sunshine, temperature, and other weather data for a specific area to determine the general pattern of weather which makes up the area's climate. *Dynamic meteorologists* investigate the physical laws governing atmospheric motions. *Physical meteorologists* study the physical nature of the atmosphere, including its chemical composition and electrical, acoustical, and optical properties, the effect of the atmosphere on the transmission of light, sound, and radio waves; and the factors affecting the formation of clouds, precipitation, and other weather phenomena. *Meteorological instrumentation specialists* develop the devices that measure, record, and evaluate data on atmospheric processes. Specialists in applied meteorology, sometimes called *industrial meteorologists*, study the relationship between weather and specific human activities, biological processes, and agricultural and industrial operations. For example, they make weather forecasts for individual companies, attempt to induce rain or snow in a given area, and work on problems such as smoke control and air pollution abatement.

Approximately one-third of all civilian meteorologists perform research on ways to modify weather, weather conditions affecting the behavior of forest fires, and other problems. Another one-third are engaged primarily in weather forecasting, and about one-fourth manage or administer forecasting and research programs. In both weather forecasting and research, meteorologists use electronic computers to process large amounts of data.

A number of meteorologists teach or do research—frequently combining the two activities—in universities or colleges. In colleges without separate departments of meteorology, they may teach geography, mathematics, physics, chemistry, or geology, as well as meteorology.

Places of Employment

More than 4,000 civilian meteorologists were employed in the United States in 1968; only about 3 percent were women. The Environmental Science Services Administration (ESSA), which includes the Weather Bureau, employed by far the largest number of civilian meteorologists—nearly 2,000—at 300 stations in all parts of the United States, the polar regions, Puerto Rico, Wake Island, and other Pacific area sites. A few worked for other Federal Government agencies. The Armed Forces employed about 300 civilian professional meterologists.

Nearly 700 meteorologists worked for private industry. Commercial airlines employed several hundred to forecast weather along flight routes and to brief pilots on atmospheric conditions. Others worked for private weather consulting firms, which provided special weather information for a fee, for companies that designed and manufactured meteorological instruments, and for large firms in aerospace, insurance, utilities, and other industries.

Colleges and universities employed about 800 meteorologists in research and teaching. Several hundred others worked for State and local governments and for nonprofit organizations.

In addition to these civilian meteorologists, more than 3,000 officers and 1,500 enlisted members of the Armed Forces were engaged in forecasting and other meteorological work in 1968. About four-fifths were on active duty in the Air Force.

Training, Other Qualifications, and Advancement

A bachelor's degree with a major in meteorology is the usual minimum educational requirement for beginning meteorologists in weather forecasting. However, a bachelor's degree in a related science or in engineering is acceptable for many positions, provided the applicant has credit for courses in meteorology. For example, the Federal Government's minimum requirement for beginning positions is a bachelor's degree with at least 20 semester hours of study in meteorology and with additional training in physics and mathematics.

For research and teaching and for many top-level positions in other meteorological activities, an advanced degree is essential, preferably in meteorology, although persons having graduate degrees in other sciences also may qualify if they have taken advance meteorology, physics, mathematics, and chemistry.

Nearly 50 colleges and universities in 1968 offered degree-credit programs in meteorology or specialized meteorological disciplines; 28 of these schools

granted Ph. D. degrees in the atmospheric sciences. Many other institutions offered courses in meteorology.

Meteorology training is given or supported by the Armed Forces. In 1968, more than 350 commissioned officers received university training in meteorology at either the undergraduate or graduate level. In addition, about 100 enlisted personnel were being sponsored in college and university programs leading to an undergraduate degree and an Air Force commission. Ex-servicemen who have experience as meteorologists frequently are qualified for civilian meteorologist positions, not only with the Armed Forces but with other employers as well.

The ESSA has an in-service training program under which some of its meteorologists are attending college for advanced or specialized training. Some college students preparing for careers in meteorology may obtain summer jobs with this agency. Promotions for regular full-time employees are made according to U.S. Civil Service Commission regulations. (See chapter on Occupations in Government.)

Airline meteorologists have somewhat limited opportunities for advancement. However, after considerable work experience, they may advance to flight dispatcher or to various supervisory or administrative positions. A few well-trained meteorologists having a background in science, engineering, and business administration may establish their own weather consulting services.

Employment Outlook

The employment outlook for civilian meteorologists is expected to be favorable through the 1970's. In addition to job opportunities resulting from the rapid growth expected in this profession, several hundred new meteorologists will be needed each year to replace those who transfer to other fields, retire, or die.

Meteorologists having advanced degrees will be in demand to conduct research, teach in colleges and universities, and engage in management and consulting work. The advent of weather satellites, manned spacecraft, world circling weather balloons, new international cooperative programs, and the use of electornic computers to make weather forecasts have expanded greatly the boundaries of meteorology and opened new fields of activity in the study of weather on a global scale. Meteorologists will be in demand to develop and improve instruments used to collect and process weather data.

Employment opportunities for meteorologists with commercial airlines, weather consulting services, and other private companies also are expected to increase, as the value of weather information to all segments of our economy receives further recognition. This recognition also may create opportunities in research positions with private research organizations and colleges and universities. The number of teaching positions for meteorologists also should rise, primarily because of anticipated increases in total college enrollments and in meteorology programs.

In addition, there will be a continuing demand for meteorologists to work in existing programs, such as weather measurements and forecasts, storm and flood forecasts, and research on the problems of severe storms, turbulence, and air pollution.

Earnings and Working Conditions

In late 1968, meteorologists having the bachelor's degree and no experience could start in Federal Government service at $7,456 or $9,078 a year, depending on their college records. Meteorologists who had completed all requirements for the master's degree could start at $9,078 or $10,154; those having the Ph. D. degree could begin at $11,563 or $12,580. Workers stationed outside the United States were paid an additional amount. Employee benefits for Federal Government meteorologists are the same as for other civil service workers. (See chapter on Occupations in Government.)

Airline meteorologists received a starting salary of approximately $8,500 - $9,000 a year in 1968, according to the Air Transport Association. Meteorologists generally receive the same benefits as other airline employees. (See chapter on Occupations in Civil Aviation.)

According to the National Science Foundation's National Register of Scientific and Technical Personnel, the average (median) annual salary of meteorologists in 1968 was $13,400. Only 10 percent of the meteorologists earned less than $9,600 and about 10 percent earned more than $19,600.

Jobs in weather stations, which are operated on a 24-hour, 7-day week basis, often involve nightwork and rotating shifts. Most stations are at airports or at places in or near cities; some are in isolated and remote areas.

Sources of Additional Information

General information on career opportunities, educational facilities, and professional development in meteorology may be obtained from:

American Meteorological Society,
45 Beacon St., Boston, Mass.
02108.

American Geophysical Union, 2100 Pennsylvania Ave., NW., Washington, D.C. 20037.

Information on employment opportunities with the ESSA Weather Bureau and on its student-assistance program may be obtained from:

Personnel Division AD42, Environmental Science Services Administration, 6010 Executive Blvd., Rockville, Md. 20852.

Information on the Air Force meteorological training programs may be obtained from the nearest USAF recruiting office or from:

Commander, USAF Recruiting Service, Wright-Patterson AFB, Ohio 45899.

OCEANOGRAPHERS

(D.O.T. 024.081 and 041.081)

Nature of the Work

The ocean, which covers more than two-thirds of the earth's surface, provides valuable foods and minerals, influences the weather, serves as a "highway" for transportation, and offers many varieties of recreation. Oceanographers study the ocean —its characteristics, movements, physical properties, and plant and animal life. The results of their studies not only extend basic scientific knowledge, but contribute to the development of practical methods for use in operations such as forecasting weather, improving fisheries, mining ocean resources, and defending the Nation.

Oceanographers plan extensive tests and observational programs and conduct detailed surveys and experiments to obtain information about the ocean. They may collect and study data on the ocean's tides, currents, and waves; its temperature, density, and acoustical properties; its sediments; its subbottom; its shape; its interaction with the atmosphere; and marine plants and animals. They analyze the samples, specimens, and data collected, often using electronic computers. To present the results of their studies, they prepare maps and charts, tabulations, reports, and manuals, and write papers for scientific journals.

In developing and carrying out tests and observational programs, oceanographers use the principles and techniques of the natural sciences, mathematics, and engineering. They use a variety of special instruments and devices that measure the earth's magnetic and gravity fields, the speed

Oceanographer hauls plankton net.

of sound traveling through water, the oceans' depths, the flow of heat from the earth's interior, and the temperature and chemical composition of the water. Specially developed cameras using strong lights enable oceanographers to photograph marine organisms and the ocean floor; new research vehicles transport marine scientists to the floor of the sea. When their work requires new oceanographic instruments or analytical techniques, they usually develop them.

Most oceanographers are specialists in one of the branches of the profession. *Biological oceanographers* (marine biologists) study the ocean's plant and animal life and the environmental conditions affecting them. *Physical oceanographers* (physicists and geophysicists) study the physical properties of the ocean, such as its density, temperature, and ability to transmit light and sound; the movements of the sea; and the relationship between the sea and the atmosphere. *Geological oceanographers* (marine geologists) study the topographic features, rocks, and sediments of the ocean floor. *Chemical oceanographers* investigate the chemical composition of ocean water and sediments, and chemical reactions that occur in the sea. *Marine meteorologists* study the interaction of the atmosphere and the ocean, and the processes by which weather over the ocean is generated. *Oceanographic engineers* and *electronic specialists* design and build the systems, devices, and instruments used in oceanographic research and operations.

About 3 out of 4 oceanographers are engaged primarily in performing or administering research and development activities. A number of oceanographers teach in colleges and universities; a few are engaged in technical writing, consulting, and in the administration of activities other than research.

Most oceanographers work part of the time aboard oceanographic ships at sea. These voyages may last from a few days to several months. A few oceanographers

work nearly all of the time aboard ship. On the other hand, some oceanographers never go to sea, but analyze data collected by other scientists or pursue mathematical or theoretical studies ashore.

Places of Employment

An estimated 5,200 oceanographers and closely related technical personnel were employed in the United States in 1968. About four-fifths were employed by the Federal Government and colleges and universities. Those Federal agencies employing substantial numbers of oceanographers were the Naval Oceanographic Office, the Bureau of Commercial Fisheries, and the Environmental Science Services Administration.

A growing number of oceanographers worked in private industry for firms that design and develop instruments and vehicles for oceanographic research. A few worked for fishery laboratories of State and local governments.

Training, Other Qualifications, and Advancement

The minimum educational requirement for beginning professional positions in oceanography is the bachelor's degree with a major in oceanography, biology, a geo-science, one of the other basic sciences, mathematics, or engineering. For professional positions in research and teaching and for advancement to high-level positions in most types of work, graduate training in oceanography or one of the basic sciences usually is required.

Undergraduate training in oceanography, marine science, ocean engineering, or fisheries was offered by only about 15 colleges and universities in 1968; and only seven institutions offered the bachelor's degree with a major in oceanography. However, since oceanography is an interdisciplinary field, training in the related basic sciences, when coupled with a strong interest in oceanography, is adequate preparation for most beginning positions in the field or for entry into graduate school.

Important undergraduate courses for the prospective oceanographer are in the fields of mathematics, physics, chemistry, geophysics, geology, meteorology, and biology. In general, the student should specialize in the particular science field which is closest to his area of interest in oceanography. For example, students interested in chemical oceanography should obtain a degree in chemistry.

In 1968, about 35 colleges and universities offered advanced degrees in oceanography, and about 30 other institutions offered advanced courses in fisheries, marine science, or oceanographic engineering. The academic work of the graduate student in oceanography consists primarily of extensive training in a basic science combined with further training in oceanography. The graduate student usually works part of the time aboard ship—doing oceanographic research for his dissertation, and at the same time acquiring familiarity with the sea and the techniques used to obtain oceanographic information. A variety of summer courses is offered by universities at the various marine stations along our coasts. These are for both undergraduate and graduate students and are recommended particularly for students from inland universities.

The beginning oceanographer with the bachelor's degree usually starts as a research or laboratory assistant, or in a position involving routine data collection, analysis, or computation. Most new oceanographers receive on-the-job training related to the specific work at hand. The nature and extent of the training vary with the background and needs of the individual. Thus, the new graduate who has a degree in a basic science rather than in oceanography usually can be provided enough understanding of oceanographic principles to enable him to perform adequately in this field.

Beginning oceanographers having advanced degrees usually can qualify for research and teaching positions. Experienced oceanographers may be selected for administrative positions, in which they may supervise a research laboratory or direct specific survey or research projects.

Employment Outlook

Employment opportunities for those having degrees in oceanography—especially the Ph.D. degree—are expected to be excellent through the 1970's. Well-trained persons with bachelor's degrees in related sciences will find opportunities mainly as research assistants in routine analytical positions.

The outlook is for very rapid growth in this profession through the 1970's. Growing recognition of the importance of the oceans to the Nation's welfare and security has heightened interest in oceanography and has opened new fields for specialists. In the years ahead, oceanographers will be needed for research in areas such as underwater acoustics, surface and subsurface ocean currents, and ocean floor topography, all of which are important in improving the Nation's defense against submarines and surface vessels. There also will be a demand for oceanographers to sup-

ply weather and iceberg forecasts; to study air-sea interaction in order to improve long-range weather forecasts; to solve sea mining problems; and to predict, control, and prevent pollution and damage caused by waves and tides. Other oceanographers will be needed to improve methods of deriving foods from the oceans, to manage fisheries, and to develop economical ways to harness the ocean for energy and to increase the supply of fresh water.

The demand for oceonographers qualified to teach in colleges and universities also is expected to expand. As interest in oceanography grows and more courses in oceanography are offered, more teachers in the science will be needed.

Replacement of oceanographers who transfer to other fields, retire, or die also will provide some opportunities.

Since oceanography is a relatively small profession, job openings will not be numerous in any one year. On the other hand, the number of new graduates having degrees in this science is small and is expected to remain so. Thus, new oceanography graduates should continue to have excellent opportunities.

Earnings and Working Conditions

In the Federal Government service in late 1968, oceanographers having the bachelor's degree and no experience could begin at $7,456 or $9,078 a year, depending on their college records. Beginning oceanographers who had completed all requirements for the master's degree could start at $9,078 or $10,154; those having the Ph. D. degree could begin at $11,563 or $12,580. Scientists in geological and biological specialties had somewhat lower starting salaries.

Beginning oceanographers in educational institutions receive the same salary as other beginning faculty members. (See statement on College and University Teachers.) In addition to their regular salaries, many experienced oceanographers in educational institutions earn extra income from consulting, lecturing, and writing activities.

Oceanographers engaged in research requiring sea voyages are frequently away from home for weeks or months at a time, sometimes living and working in cramped quarters. Young people who like the sea, however, may find these voyages very satisfying.

Sources of Additional Information

General information about oceanography—including career opportunities, professional training, colleges and universities having applicable degree-credit programs, earnings, and the economic significance of oceanographic activities—may be obtained from:

American Society for Oceanography, 854 Main Bldg., Houston, Tex. 77002.

American Society of Limnology and Oceanography, W.K. Kellogg Biological Station, Michigan State University, Hickory Corners, Mich. 49060.

International Oceanographic Foundation, 1 Rickenbacker Causeway, Virginia Key, Miami, Fla. 33149.

National Oceanography Association, 1900 L St. NW., Washington, D.C. 20036.

U.S. Naval Oceanographic Office, Washington, D.C. 20390.

Federal Government career information may be obtained from any regional office of the U.S. Civil Service Commission or from:

Interagency Board of U.S. Civil Service Examiners for Washington, D.C., 1900 E St. NW., Washington, D.C. 20415.

The bulletin *University Curricula in the Marine Sciences* may be obtained from:

Committee on Marine Research, Education and Facilities, Bldg. 159E, Rm. 476, Washington Navy Yard, Washington, D.C. 20390.

The booklet, *Oceanography Information Sources*, lists the names and addresses of many professional, research, and industrial organizations interested in oceanography. Copies, priced at $1.50 each, may be purchased from:

Printing and Publishing Office, National Academy of Sciences, 2101 Constitution Ave. NW., Washington, D.C. 20418.

The bulletin, *Marine Science Affairs—A Year of Plans and Progress*, contains information on the national oceanography program. Copies, priced at $1, may be obtained from:

Superintendent of Documents, Government Printing Office, Washington, D.C. 20402.

Some information on oceanographic specialties may be obtained from professional societies listed elsewhere in the *Handbook*. (See statements on Geologists, Geophysicists, Life Scientists, Meteorologists, and Chemists.)

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